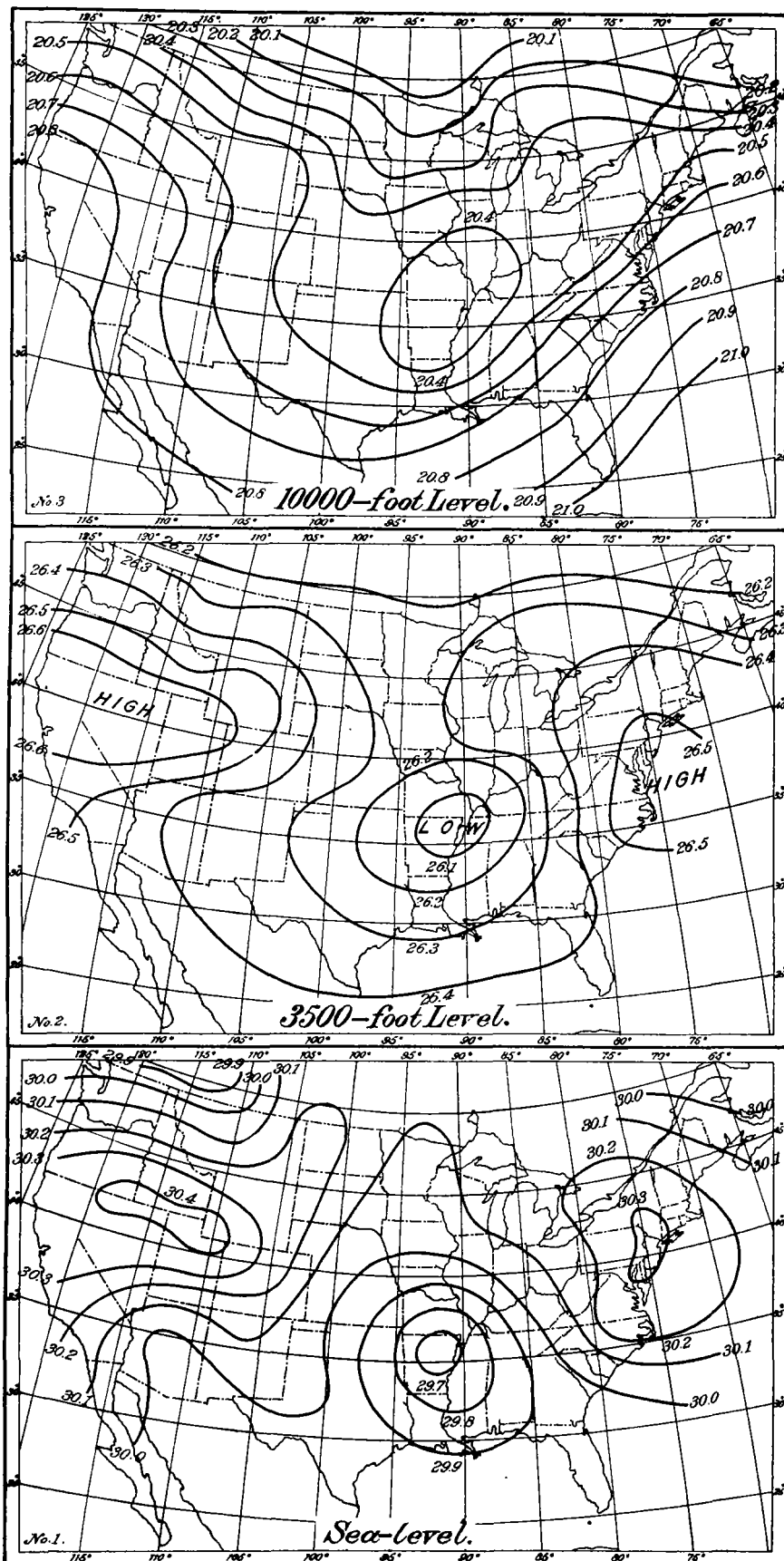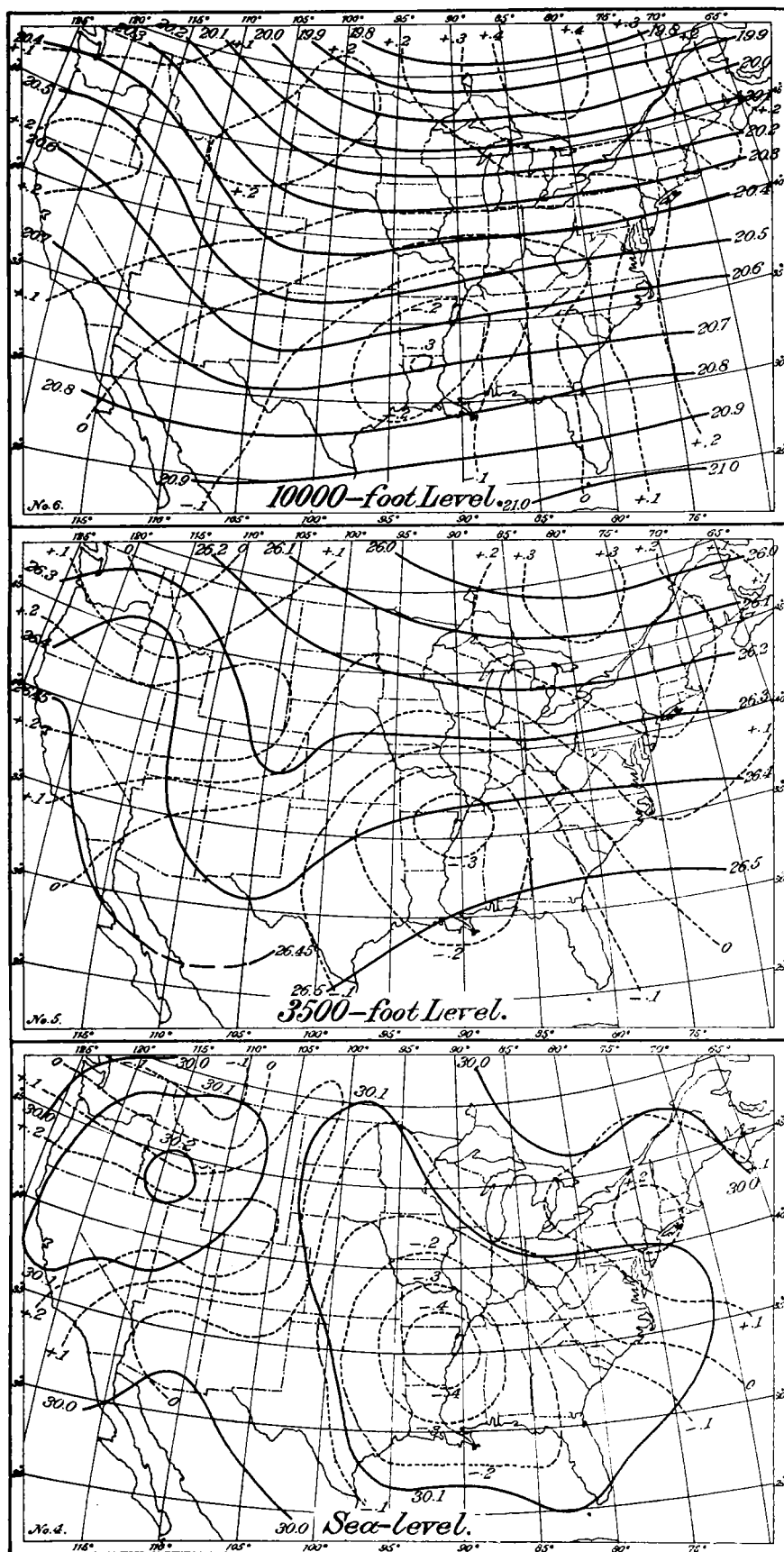## THE STRUCTURE OF CYCLONES AND ANTI-CYCLONES ON THE 3500-FOOT AND 10,000-FOOT PLANES FOR THE UNITED STATES.

By Prof. FRANK H. BIGELOW.

The reconstruction of the theory of cyclones and anticyclones depends upon the determination of the velocities and directions of the air movements, the form of the isobars, and the distribution of the isotherms at several planes above the sea level. My report on the International Cloud Observations of 1898–99 gives the result of the survey of the upper air for the vectors of motion; this was supplemented by a series of papers in the MONTHLY WEATHER REVIEW, January to July, 1902. My report on the Barometry of the United States, Canada, and the West Indies, 1900–1901, has provided the necessary means for reducing the observed station pressures to three standard planes. The observational requirements of the problem will be completed by the discussion of the temperatures and vapor tensions, which has been already begun, though it will take considerable labor to finish the research. Meanwhile, it is profitable to make use of the material at hand in a series of studies on the circulation of the atmosphere at different levels up to two or three miles above the sea level. Beginning with January, 1903, the successive MONTHLY WEATHER REVIEWS will contain charts showing the mean monthly isobars on the sea-level plane, the 3500-foot plane, and the 10,000-foot plane. By comparing these pressures with the series of normal pressures given on the charts of chapter 7, Barometry Report, we can find the departures for each month on these three planes, and a discussion of such departures from year to year, when studied in connection with other phenomena, will have an important bearing upon the discovery of the laws for use in seasonal forecasting. Similarly, monthly temperature charts are given, and these are constructed by means of the temperature gradients which can be obtained from the data in Table 48, of chapter 8, of the same report, by subtracting the values of t from t_0 (sea level), t_1 (3500-foot), t_2 (10,000-foot) in succession. The latter temperatures were found by a process which eliminated the local abnormalities contained in the observed station temperatures, and they have permanent value. The surface temperatures of the several stations need to be further revised, and so we can claim at present for the temperature gradients only an approximate correctness. This imperfection will not greatly influence the position of the mean isotherms, but the reduced temperatures of neighboring stations do not appear on the maps quite as harmonious as we hope to make them by means of the revision just mentioned.

No. 3   *10000-foot Level.*

No. 2   *3500-foot Level.*

No. 1   *Sea-level.*

No. 6. 10000-foot Level.
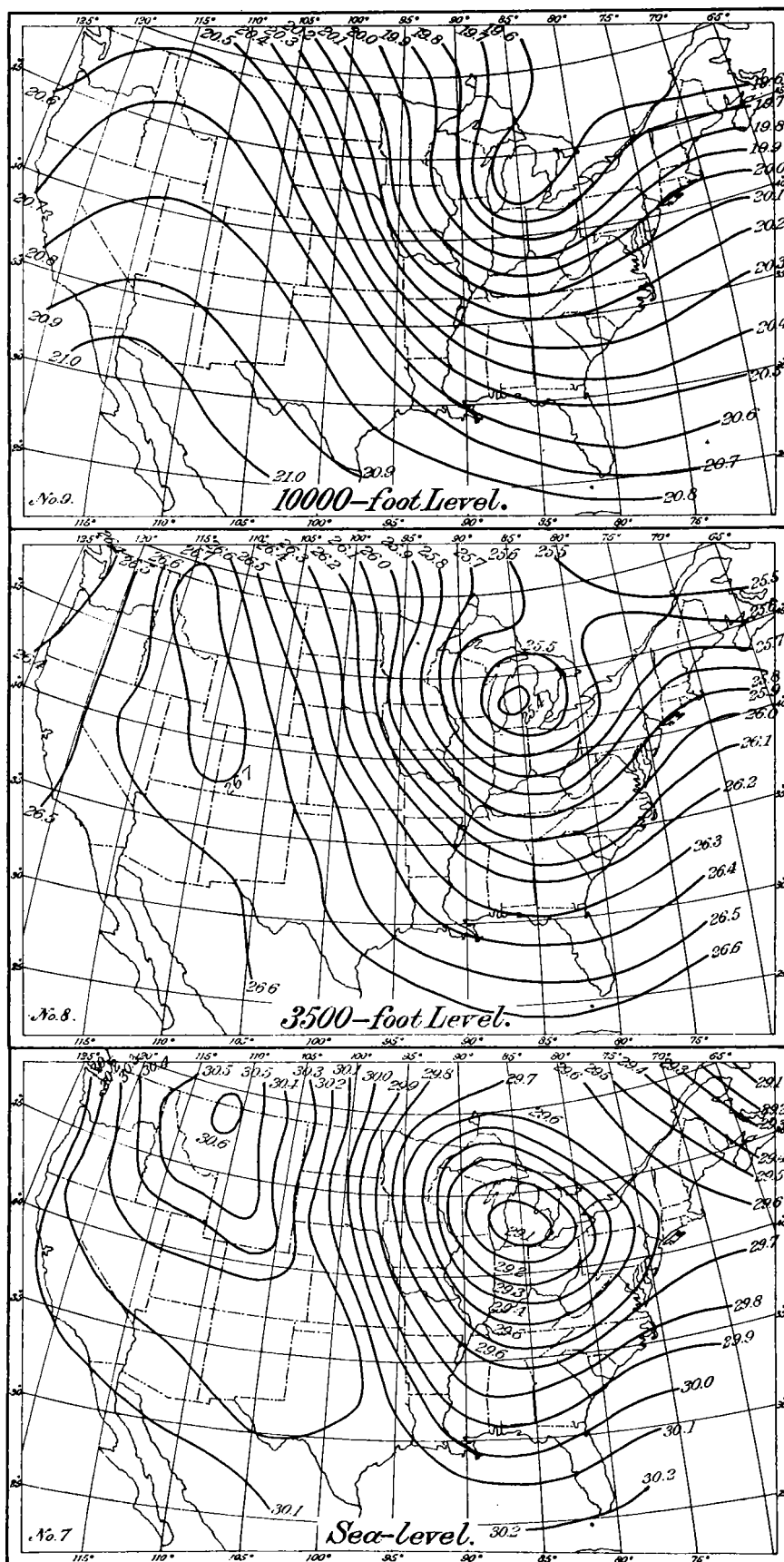
No. 5. 3500-foot Level.

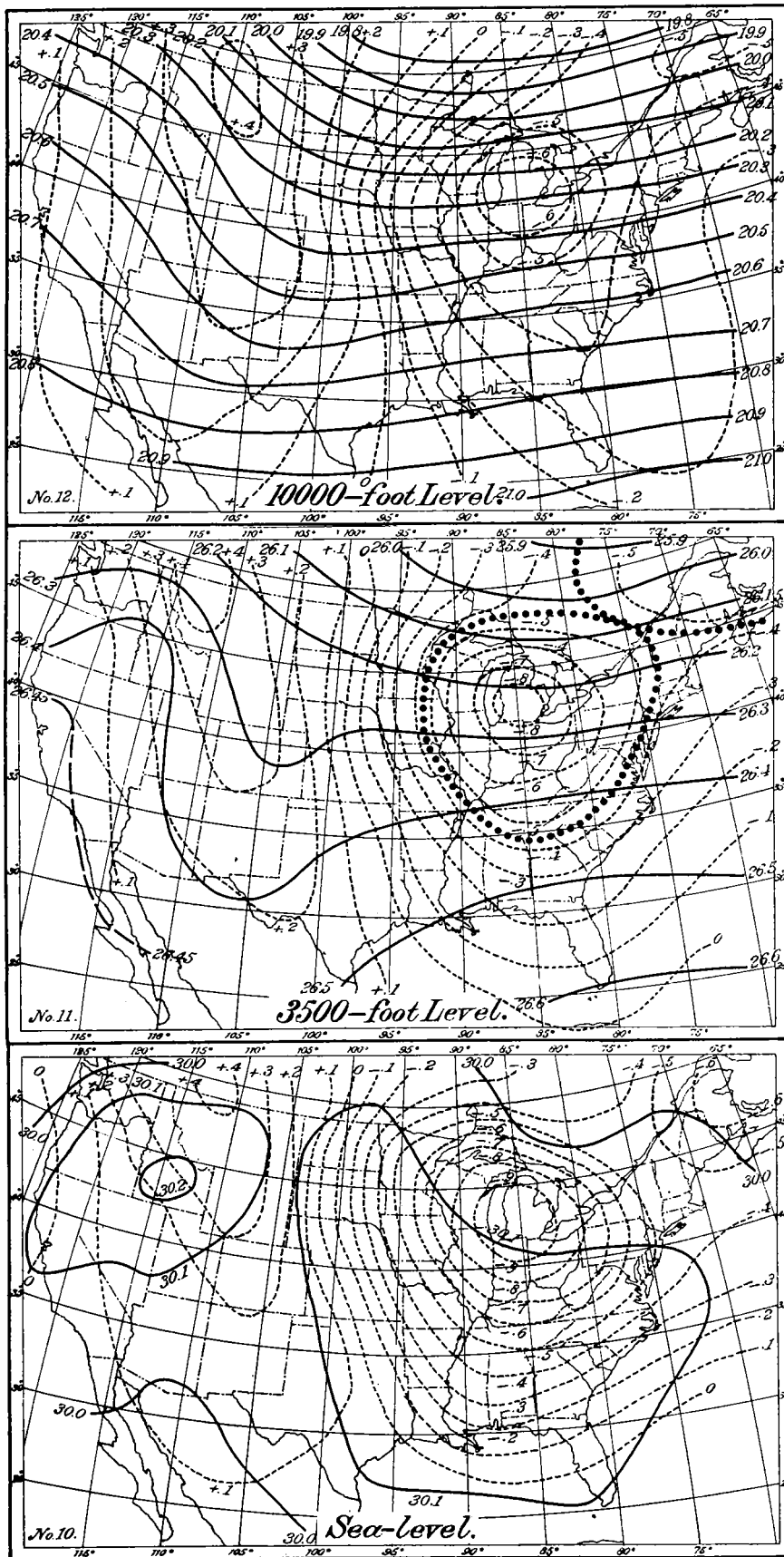No. 4. Sea-level.

EXAMPLES OF SELECTED CYCLONES.

The construction of average vectors of motion and of mean isotherms as contained in the two reports on Clouds and Barometry produces a composite or resultant chart, and this is of value in discovering general relations and laws of structure in cyclones and anticyclones. It is, however, essential to determine the conditions prevailing in individual cyclones and anticyclones if we wish to apply the theories of hydrodynamics and thermodynamics in detail, so as to compute the relations between the dynamic and thermal energies on the one hand and the resulting forces that characterize the actual storm. For this purpose the station reduction tables of chapter 9 have been expanded, and tables have been furnished to the several stations for practical service. By means of these the observers at 175 stations are enabled to mail postal cards daily to Washington containing the (B, t, e) at the station and the reduced values of the pressure for the three planes, respectively. With this data, beginning December 1, 1902, we have prepared daily charts of pressure for the United States and Canada on the sea level, the 3500-foot plane, and the 10,000-foot plane, and we propose to discuss this material briefly in the MONTHLY WEATHER REVIEW preparatory to making a suitable general report on the entire subject. Prof. R. F. Stupart, Director of the Canadian Meteorological Office, is courteously cooperating with the United States by furnishing the daily postal cards for Canada.

For the month of January, 1903, we present two cyclones—that of January 2, central in the west Gulf States, and that of January 7, central in the Lake region—in order to illustrate typical configurations of the isobars on the upper planes. It is our intention to merely mention some of the salient features of these charts, since an inspection of them will doubtless suggest their true meaning to meteorologists better than any verbal description. They have special scientific interest from the fact that this is the first exhibit of the isobaric systems in the upper air surrounding individual cyclonic and anticyclonic centers.

January 2, 1903.—Charts 1, 2, and 3 are transcripts of the isobars as derived by computation in accordance with the system contained in the Barometry Report. We note (1) that the closed isobars of the cyclone at sea level tend to diminish in number and intensity at the upper levels and that they finally open out into shallow, inflected curves at the height of about two miles; (2) these curves in opening out first form cusp-shaped curves, joined together by a pressure which is higher than that north or south of it, whereby one closed isobar and one long or open isobar of the same name occur above and below the line of the cusps; (3) the high pressures to the east and west of the cyclone diminish in area and soon fade away into the long, looping isobars of the upper strata.

We now find the general normal and the local departure components of these observed isobars as follows: (1) The normal isobars for the month are copied on tracing paper in black lines, being extracted from the January charts of chapter 7; (2) these lines are laid over the observed isobars, and a new system of lines is constructed by tracing the diagonals of the quadrilateral figures thus formed, and these new lines are shown in red lines on Charts 4, 5, and 6. These curves give us in tenths of an inch the values of the local pressure disturbances which deflect the normal isobars, and they therefore measure the pressure effect of the local cyclone proper. The causes that produce these local departures of pressure must be the same as those that produce the cyclone itself. We may assume that the upper vectors of motion are parallel to the observed isobars, and we conclude that in this particular storm a current of air from the southeast is flowing upon the United States; that a part of it curls to the left and enters the vortex of the closed isobars, which generates a vertical component, and that the rest of this stream flows away by uniting with the normal general circulation. There seems to be also a minor stream of air from the northwest, and a portion of this enters the vortex.

10000-foot Level.

3500-foot Level.

Sea-level.

No. 12.　10000-foot Level.

No. 11.　3500-foot Level.

No. 10.　Sea-level.

January 7, 1902.—Charts 7, 8, and 9, are transcripts of the reduced pressures obtained in the same way; Charts 10, 11, and 12 give the normal monthly isobars, and the local isabnormals of pressure of a typical cyclone central in the Lake region. Here, again, the central closed isobars open out first into cusps with a feeble high pressure bridge, and then into loops which become flatter with the height, and finally disappear by merging in the normal lines. It is apparent that on the west side of the center a strong current from the north is chiefly concerned in building this cyclone, a part of it curling into the central vortex which has a vertical component, the remainder escaping eastward into the normal circulation. By comparing the vectors of Chart 23, International Cloud Report (blue arrows), we see that those vectors conform very closely to these isobars, and that they are generally parallel to each other. The component vectors of figs. 6 and 7, MONTHLY WEATHER REVIEW, March, 1902, show that the deflecting vectors also follow closely parallel with the isabnormals of pressure. The agreement of these three independent researches assures us that the analysis of the structure presented in my previous papers harmonizes closely with the observed facts. It is evident that if a series of coaxial circles about the center of the cyclone be superposed upon a system of parallel lines representing the general isobars, we should obtain resulting curves similar to those that have been produced by reduction of the pressures from the surface data. This involves an equation of three degrees and three characteristic areas, one central, one above the cusp lines, and one below them. (Compare fig. 11.) This analysis will therefore enable us to pursue the mechanics of cyclones into remote details, and so we shall at length be able to compare theory and observation with much precision. The subject will be further illustrated and discussed in later papers.